SYSTEMS AND METHODS TO FACILITATE THE DELIVERY OF DRUGS

BACKGROUND OF THE INVENTION

[01] This invention relates generally to the field of drug delivery, and in particular to enhancing drug efficacy and reducing drug toxicity. More specifically, the invention relates to the drawing of blood into the thorax to increase vital organ perfusion to facilitate drug delivery.

[02] Efficient drug delivery is critical factor in treating a variety of ailments. For example, drugs often need to be rapidly delivered to patients in cardiac arrest, or when suffering from diabetes, hypoglycemia, an anaphylactic reaction, seizures, asthma attacks, and the like. In some cases, drugs have short half lives and also need to be rapidly circulated. Hence, there is a need to rapidly distribute many drugs to the blood stream and vital organs. To increase the delivery rate of certain drugs, some have proposed simply increasing the concentration of the drug. However, the increased concentration may be toxic to the patient.

BRIEF SUMMARY OF THE INVENTION

[03] In one embodiment, the invention provides a method for administering a drug to a patient. The method is designed to increase the efficacy of the drug, and in some cases to reduce the toxicity of the drug. According to the method, a valve system is coupled to the patient's airway. The valve system is configured to prevent or impede respiratory gases from flowing into the lungs for at least some time such that the intrathoracic pressure is artificially made to be less than atmospheric pressure. A drug is introduced into the patient, and the intrathoracic pressure is lowered in a repeating manner using the valve system to enhance blood to flow into the thorax. In this way, vital organ perfusion is increased to enhance the circulation of the drug. By increasing the circulation within the body with the valve system, the efficacy of the drug can be increased and less of the drug may be used to reduce the toxicity of the drug.

[04] The method may be used to enhance drug efficacy and decrease toxicity for patients with low blood pressure, those in cardiac arrest, or those who need a rapid

administration of a drug. For patients under cardiac arrest, the intrathoracic pressure may be reduced by using the valve system during standard CPR or by actively lifting the chest using a variety of CPR techniques, by electrically stimulating the respiratory and /or abdominal nerves or muscles, and the like while also preventing, restricting, or inhibiting respiratory gas flow into the lungs with the valve system for some period of time. The intrathoracic pressure may alternatively be reduced simply by breathing in while preventing or inhibiting respiratory gas flow to the lungs with the valve system. As another option, the intrathoracic pressure may be reduced by squeezing the chest and relaxing the chest with a chest caress while preventing or inhibiting airflow to the lungs with the valve system.

The valve system may be configured to prevent respiratory gases from entering the lungs until a certain threshold negative intrathoracic pressure is exceeded at which time gases may flow to the lungs. For example, the threshold negative pressure may be in the range from about 0 cm H_20 to about 40 cm H_20. At this point, the valve system permits respiratory gases to flow into the lungs. The valve system may optionally have an attached valve to create a range of positive end expiration pressures (PEEP) that typically occurs during compression of the patient's chest or when the patient exhales. This valve may be set to open when the positive intrathoracic pressure is in the range from about 0 cm H_2O to about 20 cm H_2O.

[05] The drug may be administered using a variety of techniques, For example, the drug may be introduced intravenously, through the patient's bone, through the patient's airway, including orally, nasally, and endobrochially, rectally, transdermally, and the like. As another option, the drug may be administered through a facial mask that is coupled to the patient's face or the valve system itself when coupled to the respiratory circuit.

[06] A wide variety of drugs may be introduced into the patient. These include, for example, adrenaline or other supplemental drugs used to help maintain blood pressure when the patient is in cardiac arrest. Other examples include drugs that need to be rapidly delivered, such as glucose or adrenaline. Additional drugs include sodium bicarbonate, oxygen, steroids, vasopressor drugs, anti-arrhythmic drugs, anesthetics, anti-seizure medicines, and cooling solutions to cool the brain during cardiac arrest.

BRIEF DESCRIPTION OF THE DRAWINGS

[07] Fig. 1 is a flow chart illustrating a method for delivering a drug according to the invention.

[08] Fig. 2 is a perspective view of one embodiment of a facial mask and a valve system that is used to enhance the circulation of a drug according to the invention.

[09] Figs. 3 is a perspective view of the valve system of Fig. 2.

[10] Fig. 4 is a cross sectional side view of the valve system of Fig. 3.

[11] Fig. 5 is an exploded view of the valve system of Fig. 3.

DETAILED DESCRIPTION OF THE INVENTION

[12] The invention provides various methods and systems that are designed to enhance the drug efficacy and decrease drug toxicity for patients receiving one or more drugs. Such techniques may be used with patients having very low blood pressure, patients in cardiac arrest undergoing CPR, and patients who need a rapid administration of a drug with a normal blood pressure, among others.

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[13] The invention may be implemented by enhancing the negative intrathoracic pressure within the patient's chest to in turn enhance blood flow to the thorax to facilitate circulation of the drug throughout the blood stream and to the vital organs. This may be accomplished by preventing or impeding the flow of respiratory gases to the lungs under a variety of conditions, such as when performing CPR, when causing the respiratory or abdominal muscles to contract, when actively breathing, and the like. To prevent or impede respiratory gases from flowing to the lungs, a variety of impeding or preventing mechanisms may be used, including those described in US Patent Nos. 5,551,420; 5,692,498; 6,062,219; 5,730,122; 6,155,257; 6,234,916 and 6,224,562 and US Patent Application No. ______________, filed on the same date as the present application (attorney docket no. 16354-004400), the complete disclosures of which are herein incorporated by reference.

[14] For the patient in cardiac arrest, one way to augment the negative intrathoracic pressure is by placing such a valve system in the respiratory circuit. The resistance to the inflow of respiratory gases may be set between about 0 cm H_2O and about 40 cm H_2O and may be variable or fixed, based upon physiological parameters that could be measured simultaneously, including end tidal CO_2, blood pressure, O_2 saturation, body temperature, respiratory rate and the like. As described above, the valve may be configured to decrease intrathoracic pressures relative to atmosphere pressures and extrathoracic pressures, during the performance of any kind of CPR. Its use results in a greater vacuum in the thorax relative to the rest of the body during the decompression phase of CPR. This forces more blood back to the chest, thereby increasing blood available for the next compression. This results in a greater organ perfusion. Thus, rather than requiring a large amount of exogenous drug, such

as, for example, adrenaline to help maintain the blood pressure, lower amounts of supplemental drug(s) are needed. Hence, the drug effect is more rapid and more prolonged with the valve system. In addition, the valve system reduces the potential toxicity of such types of drugs. For example, too much adrenaline is toxic to the heart. Using a lower concentration but getting a booster effect from the valve system would therefore be of benefit. The drugs can be delivered intravenously, through the bone (intraosseous), through the airway (orally, nasally, endobrochially), rectally, and transdermally. In essence, given the increased perfusion afforded by the valve system, drugs are circulated more rapidly to target sites and target organs. The valve system may be used with a variety of techniques including standard manual CPR, ACD CPR, vest CPR, phrenic nerve stimulator, and other compression devices used to perform CPR.

[15] For patients with low blood pressure, inhalation may be prevented until a negative intrathoracic pressure in the range from about 4 cm H_20 to about 20 cm H_2O is achieved to cause a vacuum in the thorax relative to the rest of the body. A phrenic nerve stimulator or chest caress device that causes a decrease in intrathoracic pressure could also be used. This draws more blood back into the chest, resulting in a greater overall cardiac output. Combining the use of the valve system with drugs results in drug availability for target organs and may cause greater effectiveness of a given concentration of drug, the half life which may be dependent upon time in the body. Thus, the maximum effect and duration of effect are enhanced using the valve system. Similarly, patients with low blood pressure secondary to vaso-vagal syncope could inhale through the valve system, increasing their blood pressure and increasing the circulation of drugs administered in a number of ways to help treat this problem. Patients with seizure disorders could similarly inhale anti-seizure medication which could more rapidly be delivered to the brain.

[16] The invention may also be used for patients who need the rapid administration of a drug. For those patients who are not necessarily in shock, such as, for example, those with diabetes and hypoglycemia, asthma, or those suffering from an anaphylactic reaction, inhalation through the valve system with simultaneous delivery of either glucose, or adrenaline, respectively, produces a more rapid onset of action of such drug effects. Oxygen will also circulate more rapidly. Thus, this invention may have widespread application as a means to enhance and facilitate the delivery of a medicinal agent(s).

[17] Drugs which have toxicity can be used in lower concentrations. Drugs that are expensive but with a short half life will circulate more rapidly. This approach could be approach could be applied to vasopressor drugs, anti-arrhythmic drugs, anesthetics, cooling

solutions to cool the brain during cardiac arrest, and the like. It can also be used to more rapidly clear toxic metabolic byproducts.

[18] Drugs may be administered via the valve system or through a face mask valve to which the valve system is coupled, from an administration site or reservoir. If drugs, or compounds like glucose, sodium bicarbonate, oxygen, or steroids, can rapidly be absorbed via the pulmonary capillary vessels, then this approach may lead to a rapid delivery and onset of action for these agents.

[19] Referring now to Fig. 1, one method for administering a drug will be described. In step 10, the patient is initially diagnosed to determine proper treatment. For example, the patient may be diagnosed as being in cardiac arrest, as having very low blood pressure, or simply need the rapid administration of a drug, such as when in shock, when suffering from diabetes and hypoglycemia, or suffering from an anaphylactic reaction.

[20] In step 20, a valve system is coupled to the patient's respiratory circuit. This may be conveniently accomplished by use of a facial mask to which the valve system is coupled. Conveniently, the actuating pressure of the valve may be varied or set to a desired threshold pressure depending upon the diagnosis. The drug is administered to the patient as shown in step 30 using any of a variety of techniques as previously described.

[21] The valve system is then used to lower the intrathoracic pressure as shown in step 40. In so doing, blood circulation is increased by creating a greater vacuum in the thorax relative to the rest of the body. This forces more blood back to the chest, thereby increasing blood circulation and vital organ perfusion during the next heart beat or when compressing the chest. The valve system may be used to lower the pressure by having the patient breathe in through the valve which prevents the flow of gases into the lungs and thereby lowers the intrathoracic pressure relative to atmospheric pressure. Other techniques that be used include actively lifting the chest using a variety of techniques, stimulating the respiratory and/or abdominal muscles and/or nerves, and the like.

[22] Fig. 2 illustrates one embodiment of a facial mask 100 to which is coupled a valve system 200. Mask 100 is configured to be secured to a patient's face so as to cover the mouth and nose. Referring also to Figs. 3-5, valve system 200 will be described in greater detail. Valve system 200 includes a valve housing 202 with a socket 204 into which a ball 206 of a ventilation tube 208 is received. In this way, ventilation tube 208 may rotate about a horizontal axis and pivot relative to a vertical axis. A respiratory source, such as a ventilation bag, may be coupled to tube 208 to assist in ventilation. Disposed in ventilation tube 208 is a filter 210 that is spaced above a duck bill valve 212. A diaphragm holder 214 that holds a

diaphragm 216 is held within housing 202. Valve system 200 further includes a patient port 218 that is held in place by a second housing 220. Housing 220 conveniently includes tabs 222 to facilitate coupling of valve system 200 with facial mask 100. Also held within housing 220 is a check valve 224 that comprises a spring 224a, a ring member 224b, and an o-ring 224c. Spring 224a biases ring member 224b against patient port 218. Patient port 218 includes bypass openings 226 that are covered by o-ring 224c of check valve 224 until the pressure in patient port 218 reaches a threshold negative pressure to cause spring 224a to compress.

When the patient is actively ventilated, respiratory gases are forced through ventilation tube 208. The gases flow through filter 210, through duck bill valve 212, and forces up diaphragm 214 to permit the gases to exit through port 218. Hence, at any time during the performance of CPR the patient may be ventilated simply by forcing the respiratory gases through tube 208.

During the compression phase of CPR, expired gases flow through port 218 and lift up diaphragm 214. The gases then flow through a passage 227 in ventilation tube 208 where they exit the system through openings 229 (see Fig. 16).

During the recovery or decompression phase of CPR where the patient's chest is actively lifted or allowed to expand, valve system 200 prevents respiratory gases from flowing into the lungs until a threshold of negative intrathoracic pressure level is exceeded. When this pressure level is exceeded, check valve 224 is pulled downward as springs 224a are compressed to permit respiratory gases to flow through openings 226 and to the patient's lungs by initially passing through tube 208 and duck bill valve 212. Valve 224 may be set to open when the negative intrathoracic pressure is in the range from about 0 cm H_2O to about –40 cm H_2O, and more preferably from about –5 cm H_2O to about –30 cm H_2O. Hence, the magnitude and duration of negative intrathoracic pressure may be enhanced during decompression of the patient's chest by use of valve system 200. Once the intrathoracic pressure falls below the threshold, recoil spring 224a again close check valve 224. In this way, circulation is increased to cause more blood to flow into the thorax and thereby increase vital organ perfusion to enhance the circulation of the drug.

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[23] Conveniently, a drug storage compartment may be interfaced with or part of a face mask system that includes the valve system. In this way, an appropriate drug may be rapidly accessed when needed.

[24] In another aspect, the valve system may be coupled to an inhalation device, such as a nebulizer, aerosolizer, dry powder dispersion device or the like where the patient

inhales from a mouthpiece to deliver a drug to the lungs. The valve system may be positioned within the airway, such as upstream of the mouthpiece, to regulate the flow of respiratory gases to the lungs as previously described. Such inhalation devices may be used to deliver medications, such as asthma medications, to the patient. The valve system may also be used to prevent gas flow to the lungs until the user generates sufficient energy to extract a drug from the inhalation device. In such cases, the threshold valve may be set to open up to about –60 cm H_2O. In this way, the valve system may be used to increase circulation of the drug as well as to create sufficient energy to extract the drug.

[25] The invention has now been described in detail for purposes of clarity and understanding. However, it will be appreciated that certain changes and modifications may be practiced within the scope of the appended claims.